Biological Evaluation

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EVALUATION OF THE DOUGLAS-FIR BEETLE ALONG THE NORTH FORK OF THE SHOSHONE RIVER AND THE CLARKS FORK OF THE YELLOWSTONE RIVER, SHOSHONE NATIONAL FOREST, WYOMING

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ABSTRACT

Douglas-fir beetle (*Dendroctonus pseudotsugae*) infestations frequently result from disturbance events that create large volumes of weakened Douglas-fir (*Pseudotsuga menziesii*) trees in the vicinity of susceptible stands. In 1988, extensive wildfires occurred in Yellowstone National Park and the Shoshone National Forest. Populations of Douglas-fir beetle increased in the fire-scorched trees. Subsequent generations of the beetles moved from these injured trees to undamaged trees in neighboring stands on the Shoshone National Forest, Wyoming.

This outbreak has moved from the Clarks Fork/Sunlight Basin area and now affects almost the entire drainage west of Cody along the North Fork of the Shoshone River. Beetle populations have erupted in the past few years within the large expanse of susceptible forest, killing many tens of thousands of Douglas-firs. Mortality evident in 2002 from beetle attacks in 2001 was far more extensive and intense than at any time since the current outbreak began. Brood sampling indicates another year of strong increase in the Douglas-fir beetle population. Because the current outbreak will continue to expand and intensify, continued high levels of mortality can be expected along the North Fork.

Deployment of anti-aggregation pheromone has successfully protected three US Forest Service campgrounds for three years. Continued use of anti-aggregation pheromones and, where possible, sanitation harvest is recommended. Long-term planning and public education with respect to this large scale change in the forest is advised.

INTRODUCTION

The Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopkins, infests and kills Douglas-fir (*Pseudotsuga menziesii*) throughout its range in North America. Typically, the beetle reproduces in scattered trees that are highly stressed, such as windfall, defoliated or fire-scorched trees (Furniss 1962; Furniss 1965; Lessard and Schmid 1990). If enough suitable host material is present, beetles can increase in the stressed trees and infest nearby healthy trees (Furniss et al. 1981). Previous research on Douglas-fir beetle infestations have examined forest stand and site characteristics associated with infestations (Furniss et al. 1979; Furniss et al. 1981; Weatherby and Thier 1993; Negron 1998) and developed models to predict the extent of tree mortality (Negron et al. 1999). Douglas-fir beetle attacks are most successful on older, larger trees found in high-density stands that contain a high percentage of Douglas-fir in the overstory (Schmitz and Gibson 1996).

The Douglas-fir beetle (DFB) has one generation per year (Schmitz and Gibson 1996). Although adult flight times vary by year, most new attacks occur in late spring to early summer on the Shoshone National Forest. Broods develop under the bark throughout the summer and early fall. The overwintering life stage can be as adults, pupae or larvae. Larvae that overwinter complete their development and emerge as adults later in the summer. A small percentage of adults that over wintered will re-emerge from the spring-attacked trees and attack additional trees in the middle of the summer.

Fires that started in Yellowstone National Park in 1988 burned onto the Clarks Fork Ranger District of the Shoshone National Forest, Wyoming, killing and scorching a large number of trees. Populations of the Douglas-fir beetle increased in scorched trees and began attacking neighboring green trees in this area (Pasek 1990). Similar events took place within Yellowstone National Park (Rasmussen et al. 1996).

This Douglas-fir beetle infestation has obviously impacted forest stand conditions over the last decade (McMillin and Allen 2000; McMillin and Allen in press). A predictive mortality model was developed based on the infestation (Negron et al. 1999). Changes in beetle populations were estimated (Pasek 1990, 1991; Pasek 1996; Pasek and Schaupp 1992, 1995; Schaupp and Pasek 1993, 1995; Allen and Pasek 1997). Additional mortality was documented since the last estimate, made in 1996 (Allen and Long 2002). Much of this additional mortality has occurred along the North Fork of the Shoshone River. This is a highly visible area, leading to the east gate of Yellowstone National Park.

Over the last 2 years, some small sanitation efforts to remove infested trees occurred along the North Fork of the Shoshone River. Also, deployment of MCH (3-methylcyclohex-2-en-1-one), an anti-aggregation pheromone, was used to protect uninfested trees in high value areas. This technique has been shown to be highly effective at reducing tree mortality (Ross and Daterman 1994, 1995; Ross et al. 2001).

MATERIALS AND METHODS

Aerial Detection Surveys

Since 1992, general aerial detection surveys have been conducted over the Clarks Fork and Sunlight Basin areas. Starting in 1998, the North Fork area was added to the annual survey. In a fixed wing aircraft, observer(s) mapped the approximate location, apparent cause, and estimated intensity of forest insect and tree disease impacts. Only recent impacts were recorded to avoid "double counting". The surveys detected trees killed by beetles the previous year, because green foliage fades to yellow and red one year after successful beetle attack. Aerial surveys were done in

July 2002.

Pheromone Trapping
Lindgren funnel traps baited with a 3-component synthetic Douglas-fir beetle aggregation pheromone were deployed and checked every 2 weeks. Traps and lures were obtained from Phero Tech, Inc, Burnaby, British Columbia, Canada.

Traps were deployed in late April, 2002, two per site. Six sites were installed in the Clarks Fork/Sunlight Basin area and six sites installed along the North Fork of the Shoshone River. Traps were checked for the first time on 16 May and maintained until 19 September, 2002.

Brood Sampling
On September 17 and 18, 2002, 6 inch by 6 inch bark samples were removed from the north and south sides of Douglas-fir trees currently infested by DFB. Sample height was 5 – 7 feet above the ground. Samples were taken from two locations along the North Fork of the Shoshone River. One location was near the Buffalo Bill Boy Scout Camp, where 17 trees were sampled, and the other location was across the highway from Eagle Creek Campground, where 19 trees were sampled. Diameter at breast height was recorded for each sampled tree. Bark samples were put into plastic bags, along with any live Douglas-fir beetles or their natural enemies, and brought back to the lab for examination. The measurements taken for each sample included the following: number and life stage of live DFB, number of DFB gallery starts, inches of DFB egg gallery, and number of each of three groups of DFB natural enemies, beetles, wasps and flies.

Use of Anti-aggregant Pheromone MCH
On April 16-17, 2002, bubble capsules containing the DFB anti-aggregant pheromone MCH were stapled to trees in the Newton Creek, Eagle Creek and Clearwater Campgrounds and the Buffalo Bill Boy Scout Camp in accordance with prescribed methods (Ross et al. 2001). The density deployed was 30-40 capsules per acre. At Newton Creek and Eagle Creek, the entire campground was treated, including a peripheral buffer strip. Only the upstream portion of Clearwater Campground was treated, because that is where all the susceptible Douglas-firs are located.

On 17-18 September, bubble capsules were removed and the treated areas completely surveyed for DFB activity.

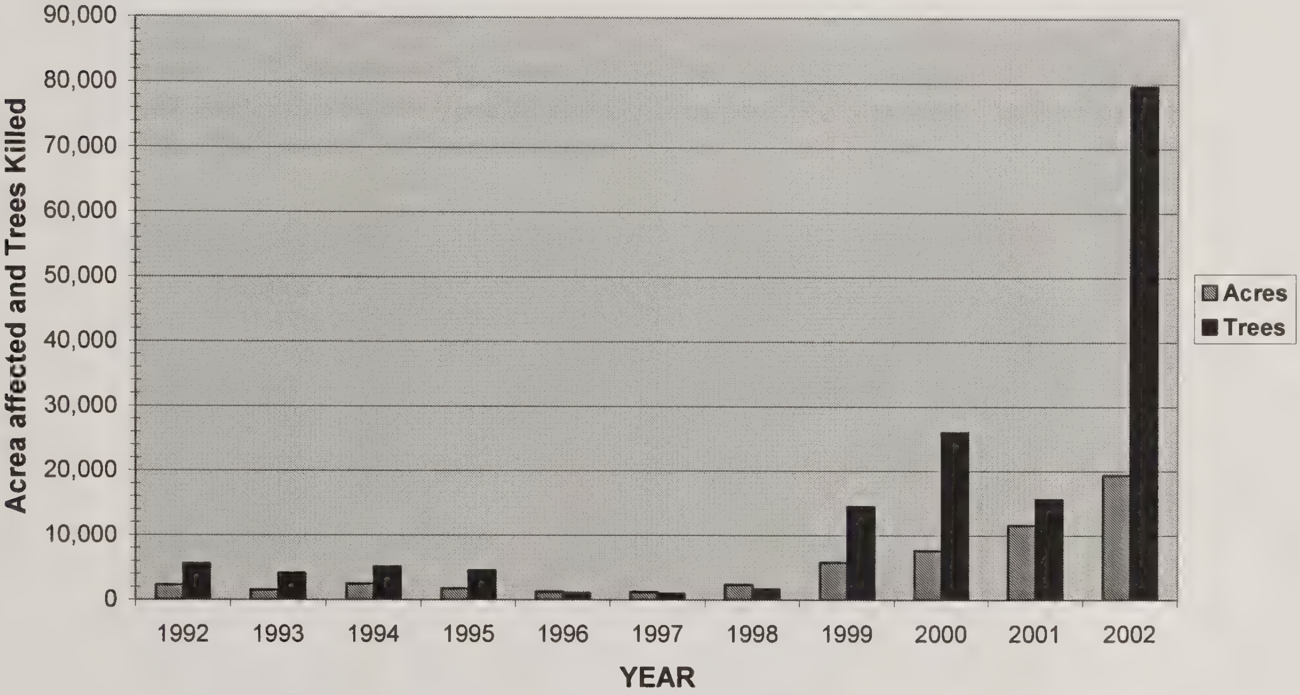
RESULTS AND DISCUSSION

Aerial Survey
General aerial detection surveys can cover large acreages rapidly and at relatively low cost per acre. Survey goals are to detect and describe, not to quantify, forest insect and tree disease impacts. Consecutive annual aerial surveys over the same area can provide trend information.

Figure 1 shows the two episodes of increasing tree mortality over the last 11 years due to Douglas-fir beetle in the evaluation area. Prior to 1998, most mortality was located in the Clarks Fork of the Yellowstone River and Sunlight Basin areas. During the last 4-5 years, most of the beetle-caused Douglas-fir mortality has been concentrated along the North Fork of the Shoshone River.

The 2002 aerial survey results show that DFB activity increased dramatically along the North Fork corridor. About 80,000 Douglas-fir trees, the result of 2001 attacks, were estimated to be fading at the time of the aerial survey. The disproportionate increase in trees killed versus acres affected suggests that the DFB outbreak has intensified more than it has spread. Virtually the entire area of Douglas-fir forest within the North Fork of the Shoshone River drainage west of Cody is affected.

Figure 1. Impact of the Douglas-fir beetle on the Clarks Fork and Wapiti Ranger Districts, Shoshone National Forest, Wyoming, based upon aerial detection surveys



Douglas-fir beetle activity in the area west of the Clarks Fork of the Yellowstone River and across the Sunlight Basin continues to be light. Less than one percent of the total number of killed trees and affected acreage was within this area. What little tree mortality that is occurring is located mostly near the western end of Sunlight Creek.

Figure 1 also illustrates that aerial detection surveys are neither intended to nor can they provide precise population estimates. The apparent decrease in trees killed from 2000 to 2001 may not be what really happened on the ground. As a tree-killing bark beetle infestation intensifies in an area, it is increasingly difficult to distinguish currently fading trees among older mortality. Small errors in estimation can be greatly magnified when thousands of trees are dying each year. In addition, the period of tree fading is long enough that not all faders are evident at one time. Nevertheless, it is obvious that a significant Douglas-fir beetle outbreak is in progress along the North Fork over the past few years and that it is increasing.

Pheromone Trapping

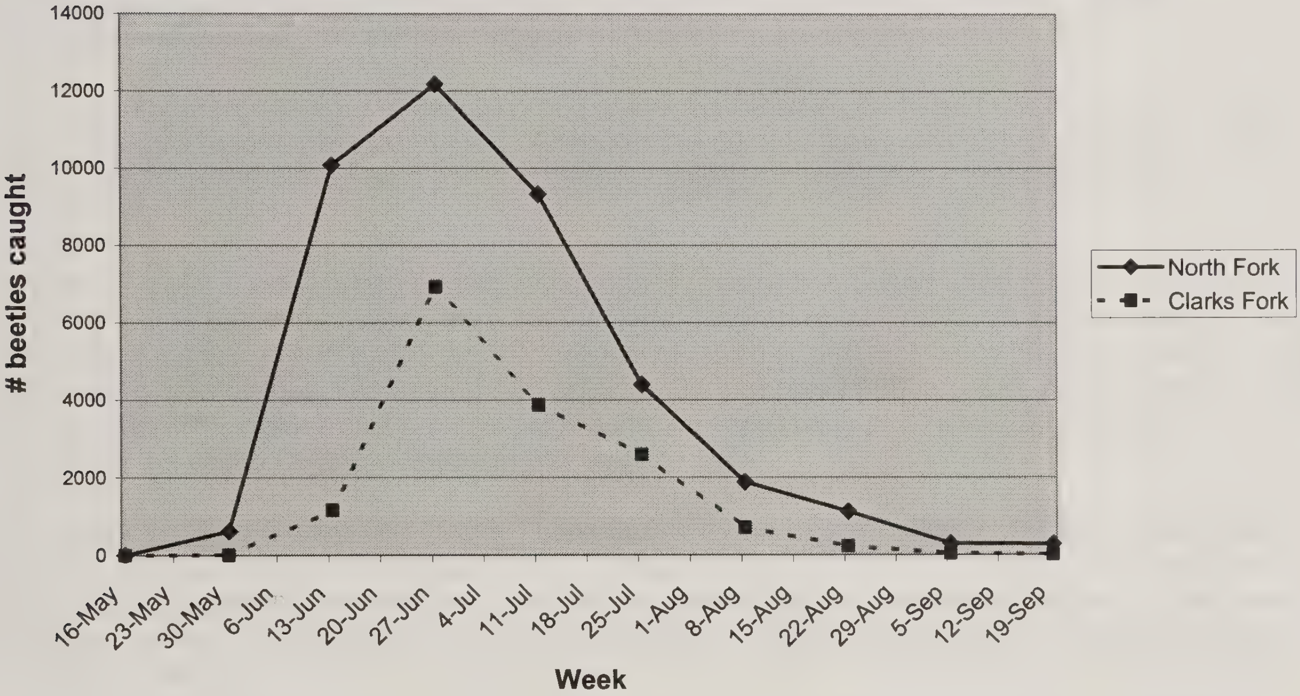
Numbers of DFB recovered from the two traps at each location were combined. One trap at Boy Scout Camp location 1 was missing in early May, so data from that site are for one trap only. Trap catch data from each location at each of the two areas were examined. The overall trend and timing of DFB catch was very similar among locations for each area. Therefore, data were combined by area.

It is assumed that DFB captured in pheromone traps are attempting to join other DFB in attacking and colonizing host trees. Trap catch plotted over time therefore defines the DFB flight and attack

period.

No DFB were caught until late May. Figure 2 shows a strong peak of trap catch in late June. On 27 June, just over half of the total trap catch for the year had been taken; on 25 July, over 90% of the total DFB catch had been taken. This means most DFB attacks on trees in these areas were completed by the beginning of August.

Figure 2. Total biweekly pheromone trap catch of Douglas-fir beetle in 2002 along the North Fork of the Shoshone River and the Clarks Fork of the Yellowstone River, Wyoming



By taking advantage of information on the timing of Douglas-fir beetle flight and attack, management activities can be coordinated to improve their effectiveness. For example, searching for trees newly infested by DFB may commence in mid August, knowing that few additional attacks will occur subsequent to the survey that year. Conversely, deployment of anti-aggregant or treatment with insecticide to protect stands or individual trees must be completed by mid May at the very latest in order to be most effective.

Caution is advised, however, in strictly applying the information from just one year of trapping data. Weather effects will delay or advance the timing of events, rather than the overall progress of DFB flight and attack. Onset, peak, and termination of DFB flight and attack can be affected. Therefore, adding a buffer of two weeks is suggested when planning management activities.

Brood Sampling
New adults were the predominant life stage recovered from brood samples (Table 1). At the Boy Scout Camp area, 92% were new adults. Overall, 63% were new adults at the Eagle Creek Campground area. Excluding two trees from the brood total that only contained DFB eggs raises the percentage of new adults to 75% at the Eagle Creek sample area.

Not all sampled trees contained well-developed DFB brood from early summer attacks. At the Eagle Creek Campground area, several trees were being attacked by DFB for the first time in mid-September. Two such trees were sampled, with three of four 6X6 inch samples containing DFB. These DFB were parent adults, not included in the sample counts, and their newly laid eggs. These eggs comprised 16% of the total DFB brood recovered there.

Overwintering immature stages of DFB have been reported before from the Clarks Fork/Sunlight Basin area (see Pasek 1996; Pasek and Schaupp 1995; Schaupp and Pasek 1995). These immatures did overwinter successfully, in some cases emerging as adults after spending a second year developing within host trees. Elevated levels of overwintering immature DFB were associated with adult emergence late in the summer. Together with adults that reemerge from prior attacks to start another brood in the same year, sufficiently large DFB populations can be present to successfully attack trees late in the summer. It may be that, as the population in the area continues to increase and expand, late summer attacks may become more common.

There was no difference among overall brood averages between north and south samples at each sample area, so results were combined. Although the sample area was 0.25 ft^2 (36 in^2) of bark surface, results are reported on a per square foot basis (144 in^2) to make comparison with other studies easier (Table 1).

The precision of the adult brood density estimates is greater 0.2, based upon the large cumulative number of brood adults recovered from the samples (Negron et. al. 2000). At the Boy Scout Camp area, 725 adults were recovered from 38 samples of 36 in^2 (0.046 m^2), while the Eagle Creek Campground area samples contained 586 adults in 34 samples of 36 in^2. This means that we have a greater that 80% chance that our sample results are repeatable and represent the actual condition of the entire DFB population in the area.

The high average DFB densities (Table 1) are similar to the higher values obtained in 1990 and 1992 in the Clarks Fork/Sunlight Basin area during the more severe part of the DFB episode there. Average DFB densities are higher than the values obtained last year in the same areas (Allen and Long 2002). These high brood densities indicate that the DFB population will continue to grow in the area sampled.

Natural enemies of DFB were rare in the samples (Table 1), although the precision of these estimates is likely to be low. An important group of DFB enemies, checkered beetles (family Cleridae), spend the winter as larvae in the root collar and were not expected to be present in samples.

Population trends can be estimated by dividing the density of new adult beetles by twice the density of gallery starts (attacks), assuming that a pair of beetles initiates each gallery start. The average density of new adult beetles represents the next generation, while the average density of attacking beetles represents the current generation. The ratio of the size of the two generations yields what is called a "population trend ratio". When the ratio of new adult beetle density to attacking adult density exceeds one, the population is increasing, and when the ratio is less than one, the population is decreasing.

The population trend ratio at the Boy Scout Camp area is 5.9:1 for emergence to attack, indicating that the population will continue to increase strongly. This ratio is similar to that found in the same area last year. The population trend ratio at the Eagle Creek Campground sample area was 6.5:1 for emergence to attack. This is nearly twice the ratio from the same area last year and indicates an even greater increase in DFB population in this area.

Table 1. Average Douglas-fir beetle brood and natural enemy density per square foot of bark surface at two locations along the North Fork of the Shoshone River, Wyoming, on September 17-18, 2002. Averages are reported ± standard error of the average.

Variable	**Buffalo Bill Boy Scout Camp area**	**Eagle Creek Campground area**
Number of Trees	17	19
Number of Samples	34	38
Average Tree Diameter	19.5 inches	20.8 inches
Eggs	0	15.6 ± 60
Larvae	6.7 ± 1.4	15.0 ± 14
Pupae	0.4 ± 0.3	6.1 ± 9.2
New Adults	85.3 ± 8.6	61.7 ± 50
Total Brood	92.4 ± 8.4	24.6 ± 9.9
Egg Gallery Starts	7.2 ± 0.9	11.4 ± 4.7
Egg Gallery Inches	107.7 ± 7.3	97.3 ± 33
Beetle enemies of DFB	0	0.4± 1.2
Wasp enemies of DFB	1.3 ± 0.5	2.2 ± 5.3
Fly enemies of DFB	1.2 ± 0.4	1.0 ± 4.0

Maximum brood production takes place when gallery starts average between 4 and 8 per square foot (McMullen and Atkins 1961). This is the case for the Boy Scout sample site (Table 1), as it was last year, providing additional evidence of a large, healthy DFB population in the area. The higher value of 11 gallery starts obtained at the Eagle Creek site (Table 1) also indicates a large DFB population, although it is less well distributed among host trees and perhaps less healthy as a result. This value is nearly twice that from 2001 in the area, also indicating a DFB population increase.

Maximum brood production can also be assessed by the amount of egg gallery length per sample. Maximum production takes place when there are 30 to 60 inches of egg gallery per square foot (McMullen and Atkins 1961). The average gallery inches per square foot are well above these values at both sites (Table 1) and also are much higher than those from 2001. Interspecific competition may somewhat reduce brood production below maximum, but this effect is likely to be offset by the large number of green infested trees in both areas that will produce attacking beetles next summer.

Use of Anti-aggregant Pheromone MCH

2002 is the third consecutive year that MCH has been deployed in the Newton Creek, Eagle Creek and Clearwater Campgrounds. It is the first year that we have treated the Buffalo Bill Boy Scout Camp, although volunteers did place MCH there in 2001.

No new DFB attacks were found at any of the three treated campgrounds. In the Eagle Creek Campground, 5 lodgepole pines had been attacked in 2002 by the mountain pine beetle, *Dendroctonus ponderosae*, and one Engelmann spruce had been attacked by the spruce beetle, *D. rufipennis*. These trees were wrapped with pink and black-striped flagging. Although increasingly active along the North Fork, impacts from these two beetle species is outside the scope of this evaluation.

New attacks by DFB were detected just inside the entrance to the Buffalo Bill Boy Scout Camp and

along the southern perimeter, mostly outside the buffer strip. The interior of the 60-acre camp had no new DFB attacks. DFB-infested trees were wrapped with pink and black-striped flagging. A total of 128 new attacks were found, most uphill along and outside the southern perimeter of the Camp.

The documented efficacy of MCH in protecting trees and stands is again demonstrated by this result. The pressure from the large DFB population is extreme, especially around the Newton Creek Campground and the Buffalo Bill Boy Scout Camp. When surveyed in 1998, Newton Creek Campground had a sizeable pocket of mortality caused by DFB. A 231 foot long by 66 foot wide (3.5 X 1 chain) transect within the campground found 25 old attacks and 12 new. The 2002 resurvey of the entire Newton Creek Campground found no new attacks and two old attacks. While the DFB outbreak has intensified in the area, MCH treatment has protected the many susceptible trees there.

CONCLUSIONS

An intense and extensive outbreak of Douglas-fir beetle is in progress that affects the Douglas-fir forests west of Cody within the drainage of the North Fork of the Shoshone River. Brood survey data, aerial detection survey information, and field observations all indicate that this beetle outbreak is large in scale, intense in impact, and that it will continue to increase in size and intensity. Barring unanticipated high levels of overwintering and dispersal mortality in the DFB population, a four to five-fold increase in Douglas-fir mortality is likely next year in the areas where brood sampling was conducted. Similar increases can be expected in many other areas where DFB activity is in progress within susceptible stands.

If no management actions are implemented, there will be further reductions in overstory basal area and average tree diameter across this landscape. Results from research conducted on the Clarks Fork/Sunlight Basin portion of this DFB outbreak estimate that Douglas-fir basal area will be reduced by 55 to 78 percent (Negron et al. 1999). In addition, the average size of trees will be reduced for the next 100 to 200 years. Regeneration and herbage production will increase in beetle-caused openings in the forest. Annual streamflow and water yield may increase where the outbreak is extensive and intense. The green foliage of recently attacked Douglas-fir will dry out, fade to a red color, and remain on the tree for one to two years. This visual impact is already quite noticeable. In addition, these red needles will provide a temporary increase in dry, flammable material in the forest canopy. The killed trees will then begin to fall down, increasing the coarse woody debris and fuel loading in the forest. The majority of the regeneration will continue to be Douglas-fir, with smaller percentages of spruce, fir, and pine.

The documented efficacy of MCH in protecting trees and stands is again demonstrated by our results. The pressure from the large DFB population is extreme, especially around the Newton Creek Campground and the Buffalo Bill Boy Scout Camp. Three years of MCH treatment have thus far kept the beetles at bay.

It is virtually impossible to stop an intense DFB outbreak already in progress for several years across a large area composed of susceptible stands. However, in areas where land management objectives are threatened by mortality of mature Douglas-fir, actions can be taken that protect individual trees, groups of trees or stands. Where wood products are the management objective, presalvage can capture the full value and use of Douglas-fir before the beetles and associated fungi degrade the wood. In addition, silvicultural treatment would be likely to mitigate future mortality from DFB by altering the conditions that facilitate tree killing by the beetles. If done on a sufficient scale over enough time, silvicultural practices can create a mosaic of forest conditions that should

reduce the size of the next episode of DFB-caused forest renewal that is bound to occur when the Douglas-fir regeneration grows into a dense, old condition again.

PEST MANAGEMENT STRATEGIES

Available pest management strategies for dealing with the Douglas-fir beetle may focus on the reduction of susceptible hosts, directly killing beetles, and/or the prevention of new beetle attacks. Methods available under each strategy are presented and briefly discussed. Not all methods are appropriate or effective in every circumstance. The decision to employ a particular strategy or combination of strategies should be predicated upon consideration of management objectives, stand conditions and location, economics, social and aesthetic values, and other factors. Where DFB is considered a pest and where action is warranted, the following strategies are available:

Strategy 1: Reduction of susceptible hosts
This is the only long-term strategy that addresses the fundamental cause of DFB epidemics, which is susceptible trees and stands.

Silvicultural treatment should be part of any ongoing vegetation management program to help increase the health of stands by decreasing their vulnerability to forest insects and tree diseases, not just to Douglas-fir beetle attack. Factors that weaken tree defense, such as root disease, can predispose an area to Douglas-fir beetle epidemics. Silvicultural treatment to reduce susceptibility to and mitigate potential mortality from Douglas-fir beetle can be used in stands either before or during beetle attack, although concurrent sanitation (see below) may be needed when treating during an outbreak.

To reduce the susceptibility of stands to Douglas-fir beetle, basal area should be brought below 80% of normal stocking (Furniss et al. 1981). Harvesting in old, mature stands and thinning in very dense younger stands should significantly lower individual stand susceptibility to subsequent Douglas-fir beetle attack.

Trees become susceptible to the Douglas-fir beetle when the combination of stand density and tree size begins to exceed the carrying capacity of the site for water and nutrients (Shore et al. 1999). The proportion of Douglas-fir in a stand and its density are important regulators of susceptibility (Furniss et al. 1981; Negron 1998; Negron et al. 1999). In unmanaged stands, beetles attack older, larger trees in denser groups (Furniss et al. 1981). Silvicultural treatments that alter these stand conditions will reduce a stand's susceptibility and subsequent mortality (Schmid and Amman 1992; Schmitz and Gibson 1996). Thinning has been suggested as a means to manage forest stands to reduce losses to Douglas-fir beetle in the Pacific Northwest (Williamson and Price 1971). Furthermore, the proportion of susceptible stands across a large area should affect the potential size and intensity of Douglas-fir beetle outbreak by impacting beetle population mortality during dispersal and attack.

The resistance of live trees to bark beetle attack is the most important natural factor controlling outbreak development (Schmitz and Gibson 1996). In addition to silvicultural treatments to reduce tree and stand susceptibility, prompt treatment of large numbers of trees that lose their resistance to attack is important in preventing outbreak induction. Any method that renders the trees unsuitable to infestation or that kills beetles once they are within these trees will be effective (see methods in Strategy 2). The Douglas-fir beetle most successfully breeds in trees injured by wind, disease, defoliation, fire or other agents. This increased reproduction allows populations to increase to such large levels that they then can overwhelm and kill otherwise healthy trees, signifying the onset of an

outbreak. The best "control" of a Douglas-fir beetle outbreak involves long term, pro-active management to prevent its occurrence (Schmitz and Gibson 1996).

Strategy 2: Directly killing beetles

There are a variety of methods available to kill Douglas-fir beetles. Killing beetles directly addresses the symptom of the problem, which is too many beetles in one place at one time, and does not address the cause of the problem, which is a susceptible tree or stand conditions. Direct control attempts are a short-term approach to beetle mitigation, unlike silvicultural treatments.

Sanitation harvesting involves removing currently infested trees from the site. Removal of beetle-infested trees can reduce the size of a localized beetle population. To be effective, sanitation harvesting should be completed before the beetles start to emerge in May of each year. Treatment may need to be repeated over several years, as some trees are always missed and immigration from untreated areas is possible. In addition to sanitation, in stands where mortality is already significant, salvaging dead trees to capture some economic value in the near future is often appropriate. However, salvage harvesting does not reduce beetle populations.

Currently infested trees can be located and treated mechanically to kill beetles developing within them prior to brood maturation and emergence. This is similar to sanitation, but employed on a smaller scale. A variety of methods can be used for mechanical treatment, including peeling bark, chipping, burning, burying, or hauling infested trees at least one mile from the nearest host type.

Douglas-fir beetles are strongly attracted to down trees such as those blown down by wind. Trap trees take advantage of this attraction by deliberately luring beetles that are then killed. To be effective, trap trees must relatively fresh. If the trap trees become infested, they must be treated before the brood matures. A variation of this method involves applying insecticide to the trap tree before it is attacked, which will kill incoming beetles before they can infest the trap tree.

Strategy 3: Prevention of new beetle attacks

Douglas-fir beetle has a well-studied complex of pheromones, airborne behavior-modifying message-bearing chemicals. Anti-aggregation pheromones, such as MCH (3-methylcyclohex-2-en-1-one), serve to regulate the density of beetle attacks by disrupting the aggregation behavior of beetles (Schmitz and Gibson 1996). MCH has been used experimentally and operationally to reduce the level of attack in high-risk areas (Ross and Daterman, 1994, 1995; Ross et al. 2001). It has been used successfully to protect areas from less than an acre to 300 acres.

Several insecticides are registered for use that can prevent infestation when applied properly prior to beetle attack. For large trees, specialized application equipment is needed. Lack of operational experience and the demonstrated success of MCH make this tactic most appropriate for use on lethal trap trees.

RECOMMENDATIONS

1. Develop a long-term strategy to deal with impacts of the Douglas-fir beetle outbreak and the use of aggressive silvicultural treatments.

It is appropriate to look at larger, landscape-level projects for the future. Many areas along the North Fork have undergone significant change and many more are still likely to be changed. Management area emphases and other land management goals may be affected in ways unanticipated before this outbreak became so intense and widespread. Estimates of mortality and

infestation probability can be determined on a stand-by-stand basis and compared with the stated objectives to provide impact predictions, regardless of which strategy or strategies are taken. Having a sound management plan for this large area will only help to provide for the future forest and the needs of the people.

In the immediate future, aggressive use of silvicultural options such as thinning uninfested stands and sanitation in infested stands should be done to the extent possible. These treatments should be undertaken as soon as possible.

2. Employ protective treatments where Douglas-fir beetle mortality is unacceptable.

The successful anti-aggregant treatments of the past few years should continue until the Douglas-fir beetle outbreak has subsided. We recommend protection of additional high value trees and stands in other areas beginning in the spring of 2003. Table 2 lists known high value areas along the North Fork corridor and the needed amount of MCH to provide for tree protection using MCH.

Table 2. Candidate areas, acreage, and estimated number of anti-aggregant capsules needed for treatment to prevent infestation by Douglas-fir beetle within US Forest Service campgrounds, permittee sites, and summer homes along the North Fork of the Shoshone River corridor, Wyoming

Candidate for Treatment	Acreage	MCH* capsules needed
Newton Creek Campground	25	625
Eagle Creek Campground	9	225
Clearwater Campground	5	125
Permittee sites (9 total)	166.8	4,168
Summer homes	64	1,920
TOTAL	269.8	6,938

* MCH = 3-methylcyclohex-2-en-1-one

3. Provide interpretation to the public

The road to Yellowstone National Park is one of the most heavily traveled in Wyoming, along which the impact of Douglas-fir beetle is obvious. Many US Forest Service interpretive sites and displays along this road provide the public with a wealth of information about their land. We recommend that the Douglas-fir beetle situation be added to this effort.

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